Fisheries and Oceans Science | Pêches et Océans Sciences

CSAS | **SCÉS**

Canadian Stock Assessment Secretariat | **Secrétariat canadien pour l'évaluation des stocks**

Research Document 2000/044 | **Document de recherche 2000/044**

Not to be cited without permission of the authors [1] | Ne pas citer sans autorisation des auteurs [1]

The stock status of Atlantic salmon (*Salmo salar* L.) in Paradise River, Labrador in 1999

D. G. Reddin, P. B. Short, R. Johnson and J. Bird[2]

Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland A1C 5X1

[2] Sandwich Bay Watershed Management Authority
P.O. Box 9
Cartwright, Labrador
A0K 1V0

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at: http://www.dfo-mpo.gc.ca/csas/

Ce document est disponible sur l'Internet à:

ISSN 1480-4883
Ottawa, 2000

Canada

Abstract

In collaboration with the Sandwich Bay Watershed Authority, an Atlantic Salmon assessment project was completed in 1999 on Paradise River, Labrador. The number of salmon entering Paradise River was estimated by mark recapture. Salmon were captured and marked in the estuary and then recaptured upstream at a tributary counting fence and in salmon traps set out in a pond in the main stem of the system. In total, about 800 salmon were caught at all sites. One hundred and fifty-six salmon were tagged and released from the lower site and, of these, 19 salmon were recaptured. The Petersen estimate of the number of salmon entering Paradise River was 5,172 salmon (95^{th} C. I. 3,283 – 8,200) consisting of 4,681 small and 491 large salmon. Spawners and egg deposition were estimated using biological characteristics from salmon sampled in the estuary traps and compared to a habitat-weighted conservation requirement for Paradise River of 13.543×10^6 eggs. In 1999, 96% of this conservation requirement was met. In 1999, 331 small salmon and 43 large salmon were counted at the Southwest Brook counting fence compared to an adjusted count in 1998 of 110 small and 4 large salmon. Also 310 brook trout were counted in 1999 compared to 199 in 1998. This is the first successful assessment of a salmon stock in southern Labrador (SFA 2) since 1996. An assessment of risk indicated a high degree of variability in the results, which can only be improved through higher numbers of marked and recaptured salmon, a more intensive sampling program and a biochemical technique to identify the sex of a salmon. In 1998 and 1999, seals were sited many times on the river sometimes feeding on trout and salmon. It is recommended that detailed studies be conducted on predator-prey interactions at a population level in Paradise River.

Résumé

En collaboration avec les responsables du bassin hydrographique de la baie de Sandwich, un projet d'évaluation du saumon atlantique à Paradise River, Labrador, a été terminé en 1999. Le nombre de saumons arrivant à Paradise River a été estimé par capture-recapture. Les saumons étaient capturés et marqués dans l'estuaire, puis recapturés en amont à une barrière de dénombrement située dans un affluent et au moyen de pièges à saumon dans un bassin du bras principal du réseau hydrographique. Au total, environ 800 saumons ont été capturés dans tous les sites. Cent cinquante-six saumons ont été marqués puis libérés dans le site le plus en aval. De ces saumons, 19 ont été recapturés. Selon l'estimation de Petersen, le nombre de saumons arrivant à Paradise River était de 5 172 saumons (IC à 95 % : 3 283-8 200), soit 4 681 petits et 491 grands saumons. Le nombre de géniteurs et la ponte ont été estimés d'après les caractéristiques biologiques des saumons échantillonnés dans les pièges de l'estuaire, puis ces données ont été comparées à l'exigence de conservation pondérée en fonction de l'habitat pour Paradise River, qui correspond à $13,543 \times 10^6$ œufs. En 1999, 96 % de cette exigence de conservation était atteinte. En 1999, 331 petits saumons et 43 grands saumons ont été dénombrés à la barrière de dénombrement Southwest Brook, alors que le dénombrement ajusté en 1998 était de 110 petits et de 4 grands saumons. De plus, 310 ombles de fontaine ont été dénombrés en 1999, comparativement à 199 en 1998. Il s'agit de la première évaluation réussie d'un stock de saumons du sud du Labrador (SFA 2) depuis 1996. L'évaluation du risque a montré beaucoup de variabilité dans les résultats, lesquels ne peuvent s'améliorer qu'au moyen de quantités plus élevées de saumons capturés et recapturés, d'un programme d'échantillonnage plus intensif et d'une technique biochimique pour identifier le sexe des saumons. En 1998 et en 1999, on a observé plusieurs fois des phoques sur la rivière, lesquels se nourrissaient parfois de truites et de saumons. Il est recommandé d'effectuer des études plus poussées sur les relations prédateur-proie à l'échelle d'une population à Paradise River.

INTRODUCTION

Labrador forms the northeastern edge of the North American continent and, covering an area of 293,000 km^2, it comprises 3% of Canada's total land mass. The linear distance from the Quebec border at Blanc Sablon to the northern most point at Cape Chidley is 1,125 km (Fig. 1). Labrador contains vast areas of freshwater found in the many streams, rivers and lakes dotting the landscape. In 1998, an assessment project was initiated on Paradise River in Sandwich Bay and repeated again in 1999. Paradise River flows northeasterly, entering Sandwich Bay approximately 20 km southeast of the community of Cartwright (Fig. 2). Paradise River has a drainage area of 5,276 km^2; the total length of the main stem and tributaries is 3,373 km with a basin relief of 485 m (Anderson 1985). The headwaters, located about 130 km from the river mouth on the Labrador Plateau, consist of a maze of small ponds and bogs (Murphy 1971). Mature stands of black spruce and balsam fir line the banks of the river (Anderson 1985). Murphy (1971) reported two partial barriers to fish migration on two tributaries but none on the main stem.

Fish species reported for Paradise River include Atlantic salmon as weil resident and migratory brook trout, white suckers, eels, and sticklebacks (Anderson 1985). Paradise River is not a scheduled river and thus there are no angling catch statistics available for it; however, local residents report very little angling activity on the river. In 1971, Murphy (1971) surveyed the rivers in Sandwich Bay and reported that 56,425 parr-rearing units (100 m^2) are available on Paradise River which, if appropriate, should be capable of producing about 17,000 adult Atlantic salmon. The salmon produced by Paradise River contributed to the local commercial fishery in Sandwich Bay as well as in other parts of Labrador the island of Newfoundland and possibly west Greenland (Pratt et al. 1974).

The main focus of this project, conducted in collaboration with Sandwich Bay Watershed Management Authority, was to assess the population of salmon in a southern Labrador river within the background of reduced commercial fisheries. This is the first assessment project conducted for a river in SFA 2, since Sand Hill River in 1996. In this paper, the stock status of Paradise River salmon is examined.

DESCRIPTION OF FISHERIES

In the past, there have been several fisheries exploiting the Atlantic salmon of Paradise River, viz. anglers in the river, commercial fishers in the estuary and in Sandwich Bay and other parts of Labrador, northeast coast of Newfoundland and west Greenland. Some salmon are also caught as a bycatch in non-salmon gear, although it is mandatory to release them. Level of mortalities of bycatches is unknown.

In 1992, several major changes were introduced to the management of Atlantic salmon in Newfoundland and Labrador. A five-year moratorium was placed on commercial salmon fishing in the island portion of the province, for the Labrador commercial fishery the quotas first introduced in 1990 were reduced, and a voluntary retirement of commercial salmon licences was

instituted for all of the province. In 1998, the commercial fishery in Labrador was closed and fishermen were offered a buyout which most accepted. The west Greenland commercial salmon fishery closed for the 1993 and 1994 fishing seasons but was open again in 1995-98. In 1999, there was a local use salmon fishery at Greenland and the commercial fishery closed. Some Paradise River multi-sea winter salmon may be caught in the Greenland fishery similar to other Labrador stocks (Pratt et al. 1974).

In the angling fishery, in 1992 and 1993, a quota on the number of fish that could be retained was introduced in each SFA. The quota was assigned for an entire SFA and was not administered on an individual river basis. Only hook-and-release fishing was permitted after the quota was caught. In 1994, quotas for the angling fishery were eliminated. In place of quotas, for Labrador, the season bag limit for retained salmon was lowered from eight to six fish, only two of which could be large salmon. In 1995 and 1996, the season bag limit for the angling fishery remained at six fish but only one large salmon could be retained. In 1999, the angling fishery was restricted to a seasonal limit of four salmon retained, one of which could be large, and four salmon could be hooked-and-released daily.

METHODS

Adult salmon estimation

A survey conducted in August of 1997 indicated that there was no suitable site for a standard fish counting fence on the lower part of the main stem of Paradise River. Consequently, an alternate technique available to enumerate fish populations was mark-recapture. The estimation of the number of animals in a population by mark and recapture requires that some individuals be marked in some way and then returned to the population. Subsequently, the population is sampled at least once and the animals examined for the presence of marks. For salmon, because they are migratory, subsequent capturing must occur at some point upstream from the original site. In this paper, sites are referred to as capture sites, which were in the estuary and recapture sites which were upstream at the Southwest Brook counting fence and in traps set out in Folletts Pond. The procedure utilised by Mullins and Caines (1999) and Atkinson et al. (1999) generating parameters for mark-recapture analysis using small salmon to estimate the population size. Large salmon were estimated based on number of large per small salmon in samples from all fishing gear in Paradise River. This approach avoids biases from generating population parameters from the relatively small sample size of large salmon.

Since there is not an extensive angling fishery on Paradise River to recapture salmon, it was necessary to fish gear both downstream to obtain salmon for marking and upstream to determine parameters for mark-recapture estimates. A counting fence was utilised to assess the number of salmon entering Southwest Brook, a small tributary stream of 300 km^2 drainage just upstream from the estuary where salmon were marked. This was done to ensure that the salmon population of Southwest was included in the population estimate for the river and to provide an alternate method of capturing salmon to estimate the number marked to unmarked fish in the population.

COUNTING FENCE

In 1998 and 1999, a counting fence was constructed on Southwest Brook, Paradise River approximately 0.5 km upstream from its confluence with Paradise River (Fig. 2). The same site was used in both years; although the installation and removal times were different. Upstream migrating fish were enumerated from 13 July to 9 September, 1998 and 18 June to 23 September, 1999. There was no time within these two time periods that the fence was out of operation. The counting fence consisted of sections (each 3 m long) which were installed according to the description in Anderson and McDonald (1978). The fence was constructed of conduit and channel iron, supported by steel posts and 5 cm x 15 cm wooden supports similar to other portable counting fences used in Newfoundland and Labrador. The fence was operated with every conduit in place so that smaller sea trout would be included in the counts; except for the period of 20-27 July when every second conduit was used due to high water.

Once the counting fence was completely installed, enumeration was done by manually releasing and counting salmon through a standard fish trap. Distinction between large and small salmon was made by comparison to a known measure placed in the bottom of the fish trap. Large salmon were defined as those salmon with a fork length equal to or greater than 63 cm and small salmon are those less than 63 cm. All other fish species encountered in the trap were also enumerated.

In 1998, the counting fence was installed too late to count the entire run. The 1998 count was adjusted using distribution data from 1999 so that the 1998 count as best as possible reflects the entire run into the river in that year. Prior to the installation in 1998, salmon counts were adjusted proportionately to counts in the same period in 1999. This was thought to be a satisfactory adjustment technique as salmon arrival time was similar in both years.

MARK RECAPTURE

In 1999, the fishing gear used in the capture and recapture of salmon were of two types. The first was a modified salmon trap with a double leader set in a "V" shape. The second, termed an along-shore trap, was basically a box trap with a single leader extended into shore from the trap. Four traps were used in five locations on the Paradise River system with two (one of each type) being set in the estuary for capturing salmon to mark and initially two in Folletts Pond for capturing salmon to examine for the presence of marks. One of the estuary traps was moved in August to Folletts Pond after catches in the estuary had dropped off. All traps were covered with a partial roof.

The traps and leaders were constructed of 1 5/8 inch knotless nylon twine and consisted of a rectangular shaped trap 60 ft x 16 ft in size with one trap being 18 ft deep, two traps were 14 ft in depth and another was 12 ft deep. Traps of various depths were used at different sites to match the water depths.

For the modified salmon trap with the "V" shape leader, the length of the leaders varied by site

with the leader nearest shore or the inside leader generally going to shore and being 50 - 125 fathoms in length. The outside leader that was generally set towards the middle of the river or pond was approximately 50 fathoms in length. The depth of the leaders usually was the same depth as the trap it was attached to with the exception of the sections of leader closest to shore being shallower. The door of each trap was at the inside edge of two net panels that extended back into the trap and on the other end extended out in a "V" shape and was attached to the two leaders. The width of the door or openings was approximately 18 inches. These traps were constructed with an inside compartment that salmon entered through a second 6'x 4' door. The traps were set with the 60 ft side orientated parallel to the current. The leaders were set out in a "V" shape facing downstream. A short leader (approximately 3 m long) was attached in the middle of the "V" to guide salmon to the door. Traps and leaders were either attached to shore or anchored. Usually this was done with grapnels but at one recapture site in Folletts pond piers were used to anchor the trap and approximately 450 fathoms of leader was used block off the end of the pond.

The along-shore traps used were the same size (60' x16') but only had one leader extending from a door on the side of the trap to shore. The traps were orientated with the long side parallel to the shore.

MARKING (TAGGING) TECHNIQUES

Salmon tagged from the traps were dipped from the trap and placed in a holding tank in a boat. Once the trap hauling was completed the boat steamed away from the trap and the fish were tagged and released. The fish were tagged with blue T-bar Anchor tag series S3000 and were attached with Dennison tagging guns. All salmon were tagged on the left side of the fish with the tag being attached through the anterior section of the dorsal fin near the base. Fork length (FL) and a scale sample were taken from each fish. Only salmon in good condition were tagged and released. All salmon were released upstream from the capture site.

ESTIMATING POPULATION SIZE

The estimation of the number of salmon entering Paradise River was carried out using two approaches. Returns of small salmon past the estuary traps were calculated from the pooled tags applied at those sites and recovered at the counting fence and upstream traps at Folletts Pond in two ways. First, was the traditional approach developed by Petersen (1896) and second, was a Bayesian estimator as described by Gazey and Staley (1986). The most probable population size given R recaptures out of M marks placed in a sampled catch of C was calculated over a range of possible population sizes assuming a binomial distribution. A tag loss rate was factored into the calculations based on examination of individual salmon for tag scars at the recapture sites.

Petersen single-census method (Ricker 1975):

$$N = M * C / R,$$

Where,

M = number of marked fish in the population,
C = total catch of small salmon, and
R = number of marked fish recaptured.

The assumptions of the Petersen estimator are that (1) marked fish have the same rate of natural mortality as unmarked, (2) the marked fish are as vulnerable to capture as unmarked, (3) marked fish do not lose their mark, (4) marked fish become randomly mixed with the unmarked, and (5) all marks are recognised and recorded. Assumption (1), (2) and (4) were assumed to be constant, (3) was corrected by estimating a tag shedding rate and adjusting the number of marked fish accordingly and (5) was made negligible by carefully examining each fish individually.

Returns of large salmon to Paradise River for either method were computed as a proportion of all salmon sampled in estuarial traps, counting fence, and in Folletts Pond. The assumption of equal distribution of capture rates was examined by using the SPAS software developed by Arnason et al. (1996).

Biological characteristics

Biological characteristics of adult Atlantic salmon were obtained from catches in the marking traps in the estuary. Information on fork length, sex (determined internally), and scales were removed to be aged. Mortalities in marking and recapture traps and at the counting fence were measured for fork length (cm), whole weight (kg), sex, and scales were removed for ageing.

Fecundity values used for Paradise River salmon were from Sand Hill River, the only river in Labrador where fecundity has been measured (O'Connell et al. 1997). Fecundity is determined as the number of eggs per kg of whole weight or number of eggs per cm fork length. The ovaries were collected from the angling fishery on Sand Hill River in 1994 and 1995 and indicated that the mean total egg count per small salmon was 3,808 eggs (n=96) and 5,096 eggs (n=23) per large salmon (O'Connell et al. 1997). Relative fecundity for small salmon from Sand Hill River was 1,998 eggs per kg and for large salmon 1,094 eggs per kg. In terms of fork length, relative fecundity was 68.2 eggs per cm for small salmon and 67.5 eggs per cm for large salmon. In the absence of samples from Paradise River, the Sand Hill River fecundity values were used.

Total river returns, spawning escapement, and egg deposition

TOTAL RIVER RETURNS

Total river returns (TRR) were calculated separately for small and large salmon as follows:

$$TRR = FC + RCb + HRMb$$

where,

FC = fish count at counting fence
RCb = angling catch below counting fence
HRMb = hook & release mortalities evaluated as 10% of hook & released fish the below counting fence.

SPAWNING ESCAPEMENT

Spawning escapement (SE) was calculated as the difference between the number of fish returning to the river (TRR) minus the angling catches of retained salmon above and below the fence (AC) minus 10% of hook and released salmon above the counting fence.

$$SE = TRR - (ACa + HRMa) - (ACb - HRMb)$$

where,

ACa = angling catch above the counting fence
ACb = angling catch below the counting fence
HRMa = hook & release mortalities evaluated as 10% of hook & released fish above the counting fence.

EGG DEPOSITION

Egg deposition (ED) was calculated separately for small and large salmon and then summed as follows:

$$ED = SE \times PF \times RF \times FL$$

where,

SE = number of spawners,
PF = proportion of females,
RF = relative fecundity (No. of eggs per cm), and
FL = mean fork length of female salmon

Accessible parr-rearing habitat

The entire watershed of Paradise River is accessible to migrating Atlantic salmon (Anderson 1985). Paradise River has a drainage area of 5,276 km^2; the total length of the main stem and tributaries is 3,373 km (Murphy 1971). Downstream from the headwaters for 75 km the river has a low gradient, an average width of 100 m, and provides good salmonid rearing habitat. The river gradient is steep 35 km from the river mouth where there are a series of rapids. The river below the rapids is made up of a series of wide (300 m) steadies and a couple of large ponds and is generally considered poor salmonid habitat. None of the small tributaries were surveyed in this section either; although, the main stem is included in habitat estimates (Fig. 2). From his survey, Murphy (1971) recorded a total of 56,425 rearing units on the main stem and the several tributaries that were measured (Anderson 1985); although some tributaries were not measured. One of these was Southwest Brook were the counting fence was installed. Pond habitat was not

surveyed and is not included in the estimates of parr-rearing area. Fish species recorded for this river include suckers, salmon, trout (resident and sea), sticklebacks, and eels. Murphy (1971) estimated that Paradise River is capable of producing ~17,000 adult salmon.

Conservation requirements

The minimum egg deposition requirement for conservation in Paradise River was derived using egg deposition rates of 240 eggs per 100 m^2 for fluvial parr-rearing habitat (Elson 1957; 1975; Chaput 1997). Although this value may be habitat and river specific for river systems from which they were derived, they represent the best available data and are used as a general baseline for determining stock status of Paradise River. Biological characteristics used to calculate the conservation requirements in terms of eggs are from data collected in 1999.

Analysis of risk

The accuracy of egg depositions and percent of egg conservation requirements met is very important as it describes the status of the salmon stock in Paradise River and is used by fisheries managers. Accuracy of these estimates was investigated by risk analysis through a simulation exercise that investigated the variability around several key parameters and the effect of this variability on total returns to Paradise River, egg deposition rates and the percent of conservation requirements met. Estimation of total returns was based on mark recaptures of small salmon which has a great deal of variability due to the number of tagged salmon caught and numbers of salmon examined for tags. The effect of variability in total returns was examined assuming a binomial distribution of tagged:untagged small salmon and large salmon per small salmon return. Egg depositions will vary depending on the numbers of small and large salmon estimated entering Paradise River and sex ratio, relative fecundity, and fork length. To account for all sources of variability and their magnitude, we assumed a range of values for each parameter. Thus, relative fecundity was set to vary at ±10% for small and large salmon and fork length was set to vary at ±10% for small salmon and ±20% for large salmon. Spawning escapement was assumed equal to total returns. Egg depositions and percent of the conservation requirement met were calculated using 5,000 realisations from a uniform distribution for fecundity and fork length, while a binomial distribution was used to evaluate mark recapture estimates of small returns, the ratio of large to small salmon used to estimate total returns, and proportion female. Input values were from biological characteristics and mark recapture data collected in 1999.

Environmental data

During field operations, environmental data were collected at the fence site. Water temperatures were recorded by Hugrun thermograph set at 1 m from the surface at the fence site. Cloud cover, relative water levels, weather conditions and air temperatures were also recorded.

RESULTS

Adult salmon estimation

Complete counts at the Southwest Brook counting fence were obtained in 1999 and counts from 1998 adjusted using the 1999 proportionate daily run. Mark recapture estimates were made of the population swimming past the estuary.

COUNTING FENCE

Table 1 gives the daily count of fish counted through the Southwest Brook fence and Table 2 shows the daily, cumulative and percent cumulative totals for 1998 and 1999 with corrections for 1998. In total, there were 67 small salmon and 3 large that passed through the fence from 13 July to 9 September, 1998. Other fish counted were 187 brook trout and 10 suckers. In 1999, there were 331 small and 43 large salmon passed through the fence from 18 June to 23 September. Other fish counted were 310 trout and 61 suckers. Salmon counts are complete except for a few salmon that may have entered after the fence was removed. Entrants into Sand Hill River which is to the south of Paradise River where counting extended into October are very low after the end of August (Reddin et al. 1996). Most salmon and trout passed through the counting fence during the first three weeks of July. In 1998, 4% of the run were large salmon and 11% in 1999 (Tables 2 a&b).

Comparison of counts of salmon and trout at Southwest Brook in 1998-99 are shown in the text table below. First, is a time period comparison whereby counts during 13 July - 9 September which was the time of operation in 1998 are shown for both years.

	Salmon			
Year	**Small**	**Large**	**Total**	**Trout**
1998	67	3	70	187
1999	202	32	234	292

Second, is the results of correcting the 1998 counts using the 1999 proportionate run for the same time the fence was non-operational in 1998:

	Salmon			
Year	**Small**	**Large**	**Total**	**Trout**
1998	110	4	114	199
1999	331	43	374	310

Interesting that both salmon and trout have increased substantially from 1998 to 1999. Increases for salmon were expected from previous analyses using commercial fishing data to calculate total

returns and spawners to Labrador rivers (CSAS 1999). Spawners producing returns were generally increasing. Local DFO Fisheries Officers report that trout have been increasing in recent years after a period of decline.

MARK RECAPTURE

One hundred and sixty-three small and large salmon were captured at the estuary tagging sites; of which, 156 were tagged and released. There were seven mortalities. Of the total number of salmon tagged and released, 154 salmon were tagged from traps 1 & 2 and 2 salmon were tagged from gill nets set in the same area. At the upper trap site 3, 171 salmon were captured of which three were previously tagged. Thirty-seven were tagged and released. All other fish were released untagged. At trap 4, 50 salmon were caught of which one had been tagged at site 3. Only estuary releases and subsequent recaptures were included in the mark recapture analysis.

Of the 156 salmon tagged and released from the estuary sites there were 18 were recaptured. Three salmon were recaptured at the upper site 3 and 15 at the counting fence on Southwest Brook (Table 3).

Other fish caught in the lower estuary traps were 6 salmon parr, 117 salmon smolt, 221 brook trout, 349 smelt, 149 suckers, 135 rock cod, 36 herring, 3 flatfish, 2 Atlantic cod, 37 tomcods, 1 sculpin, 1 eel, 1 shad and 1 lumpfish. At the upper trap site other fish caught included 9 salmon smolt, 14 brook trout, 1 charr, and 1 pike.

In total, there were 18 tagged salmon recovered from the 156 tagged in the estuary traps and gillnets (Tables 4). At the counting fence, there were 374 small and large salmon counted, of which, 15 salmon were tagged (Table 4). In Trap 3 at Folletts Pond, there were 171 salmon caught of which 3 bore tags. In Trap 4 at Folletts Pond, there were 50 salmon caught none of which bore tags from the estuary tagging. One large tagged salmon tagged in trap 3 in Folletts Pond was recovered at trap 4. Tag loss or shedding rate was calculated from examination of all salmon for tagging scars at both recapture sites. In total, one out of 374 fish examined at the counting fence had a scar and no tag for a tag loss rate of 0.0001 per day. Out of 221 salmon caught and examined at Folletts Pond, none had tag scars for a loss rate of 0. In total, there were 36 double tagged salmon released from the estuary and out of five recoveries, one had lost a tag for a loss of 0.014 tags per day. An arbitrarily chosen tag loss rate of 0.001 tag per day was used to determine tagged salmon available for recapture which results in a correction factor of 0.986. Of the 145 small salmon originally tagged there were 143 available for recapture.

The population estimate for Paradise River salmon was derived using data for small salmon only of 143 tags available for recapture (adjusted from 145 to account for tag shedding), 16 recaptures (sum of counting fence plus trap 3), and 535 salmon examined for tags (sum of counting fence plus trap 3 catches). The Petersen estimator of population size is 4,681 small salmon (95th C.I. 2,881 – 7,613). Precision of this estimate is about 40%. In total, 758 salmon were caught and of these, 686 were small and 72 were large. This was deemed to be a representative sample of the population in the river and was applied to the estimate of small salmon. The estimate of returns is 4,681 small salmon (95th C.I. 2,881 – 7,613), 491 large salmon (95th C.I. 402 – 587) for a total

of 5,172 salmon (95th C.I. 3,283 – 8,200).

Small salmon returns estimated by other functions were also examined for comparison to the Petersen estimator. The Bayes maximum likelihood estimate of small salmon is 5,020 (95th C.I. 3,160 – 8,620). The maximum log-likelihood estimate of small salmon is 4,782. Of these, the Petersen estimate is lower than Bayes and similar to the log likelihood. However, the similarity of the three estimates adds a level of confidence to the Petersen estimate, but since all three estimates are derived using the same data set they are not entirely independent.

BIOLOGICAL SAMPLING

Biological sampling was done from 207 tagged salmon and mortalities from the lower and upper sites (Table 5). The percent female in the 14 mortalities that were sexed was 64.3%. There were 190 (91.8%) small and 17 (8.2%) large salmon. There were 95.1% 1-sea-winter salmon, 3.4% 2-sea winter salmon, and 1.5% were repeat spawning salmon. The mean FL. for small salmon was 56.3 cm (SD=2.92, n=190) and the mean FL for large salmon was 69.5 cm (SD=6.75, n=17). The river age distribution of all salmon was 1% - 2 years, 14% - 3 years, 49% - 4 years, 30% - 5 years, 5% - 6 years, and 2% - 7 years. Thus, the river or smolt age is predominately 4 and 5 year olds (79% of fish sampled).

Accessible parr-rearing habitat

The estimate of 56,425 parr-rearing units for Paradise River is a minimum value as the rearing areas of tributaries in the lower section of the river and parr production in ponds were not included (Murphy 1971). Another source of error is that all linear distances were measured using 1:250,000 scale maps and were measured by hand-held planimeter. Comparison of habitat measured on 1:50,000 scale maps versus the 1:250,000 scale maps indicates that some habitat will be excluded.

Conservation requirements

The estimated conservation requirements in eggs for Paradise River are as follows:

Fluvial Rearing Units: 56,425 (100 m^2)
Lacustrine Rearing Area: Not included

Standard Conservation Egg Deposition Requirements:

Fluvial = 240 eggs per rearing unit

Egg Deposition Required for Conservation

= Conservation egg requirements * Accessible parr rearing habitat

= 240 * 56,425

= 13,542,000 eggs

Total river returns, spawning escapement, and egg deposition

In 1999, the total river returns and spawning escapement to Paradise River were estimated at 4,681 small and 491 large salmon (Table 5). There is very little angling activity on Paradise River and thus total returns are equal to spawning escapement.

In 1999, egg deposition was estimated at 13.0 million eggs which was 96% of the conservation requirements (Table 5). This estimate has several possible sources of error. First, although probably low in number, there were potentially returns of salmon to the river after the mark recapture project ended. Second, sample sizes used to derive sex ratios are low. Third, is the use of 1;250,000 scale charts for habitat measurements and non-inclusion of some tributary streams which to some degree will under-estimate habitat.

Conservation requirements achieved in 1999

The percent of conservation requirements met in 1999 was 96%.

Analysis of risk

In determining total returns, egg depositions and conservation requirements met in the previous sections, few of the parameter values were known with certainty. Specific levels of variability and distribution were assumed for each of the parameters in the assessment and 5,000 realizations made (Table 7). With these assumptions, Paradise River would have achieved 5,276 returns of small and large salmon at the 50th probability level (Fig. 5). The corresponding 5th and 95th percentiles of the percentage of total returns to the river were 3,761 and 8,543 salmon, respectively. Egg deposition from small and large salmon at the 50th percentile was 13.2 million eggs which represents 96% of conservation requirement of 13,542,000 eggs also at the 50th percentile (Figs. 6 & 7). The corresponding 5th and 95th percentiles of the egg deposition were 7.7 million and 24 million and percentage of conservation requirement met were 57 and 178%, respectively (Figs. 6 & 7).

Environmental Data

Figure 8 gives the daily water temperatures and water heights at the counting fence on Southwest Brook. Mean daily water temperature ranged from a low of 10 °C to 21 °C with an overall mean of 15°C. On several occasions, water temperatures on Southwest Brook exceeded 18 °C peaking at 24 °C early in the season and then declining at the end. Hook and release mortalities are thought to begin at around 18 °C. Water levels ranged from a low of 26 cm to 84 cm with a mean of 57 cm.

DISCUSSION

In 1999, it was estimated that 4,681 small and 491 large salmon returned to Paradise River, Labrador. The egg deposition achieved was 13.2 million eggs and percent of conservation requirements met was 96%. An assessment of risk indicated that there was a high degree of uncertainty in several of the parameter values used to make the population estimate including percentage female and the effect of the number of tagged salmon recovered during the mark recapture program. A risk analysis suggested that the number of salmon estimated to have returned to Paradise River in 1999 ranged from about 3,800 to 8,500 and the percent of conservation requirements met ranged from 57% to 178%. Better results in terms of narrower confidence limits can be achieved by recapturing and tagging more salmon and by having higher sample sizes for sexed fish. If the population size is similar in another year then more trapnets will be required to catch more salmon. The salmon traps were improved in 1999 over 1998 by the addition of roofs and alterations to the leaders and doors. These changes seem to have increased the number of salmon caught particularly at the recapture sites in Folletts Pond. Because there is little angling activity on Paradise River there is no source of dead salmon to obtain sexed samples from. Since sex determination can only be done throughout the run by killing fish an alternate method of sex determination is required.

Other important parameter values were the number of tags shed from tagging to recapture sites, differences in mortalities of tagged salmon versus untagged, and their unequal distribution over time. Other studies using similar tags are available to compare with tag shedding of 1.4% used in this study. In Scotland, Floy tags have been used extensively on Atlantic salmon with a shedding rate of about 1.5% over a similar time period to the Paradise River study (J. McLean, pers. comm.). Mark recapture has also been used to estimate the run size of Atlantic salmon into the Buctouche River, New Brunswick. Tag shedding was assumed to be zero for the month over which the study took place (Atkinson et al. 1999). Evaluation of anchor tags used on cod revealed tag shedding of 10% over a year at sea while tag loss was negligible over three months in holding experiments (Ottera et al. 1998). Results of these other experiments suggest that the 1.4% tag shedding rate used in this paper is reasonable. Tagged and untagged salmon were assumed to have the same mortality rate between tagging and recapture sites in the Paradise River study. Unequal capture rates were shown to be quite different but due to the low recaptures outside of the 1st recapture period suggest that unequal capture rates have little effect on the estimates of population size in this study.

The low numbers of salmon marked, released and subsequently recaptured used to estimate population sizes are low. In 1998, it was not possible to estimate population size of salmon entering Paradise River due to the low numbers of salmon caught. The counts on Southwest Brook indicate that the numbers of salmon and trout in 1999 more than doubled over those of 1998. In 1999, the proportion of salmon caught in the estuary was about 3.2% of these entering Paradise River. If it is kept in mind that the traps were improved in 1999 over 1998 perhaps increasing the proportion of the run caught and applying the it to the 1998 salmon catch in the estuary suggests that 4,900 salmon may have entered Paradise River in 1998.

The overall accuracy of mark recapture to estimate population size is of relevance. There are not

many experiments similar to ours based on a known population size with which to judge the accuracy of results. However, an experiment in the Pacific on Masu salmon whereby salmon were counted at a fence and estimates by mark recapture were also made (Miyakoshi & Kudo 1999). The Petersen estimate of the population was 11% higher than the actual number; although the confidence limits encompassed the known number. A few examples where testing of estimates from the various estimators of population size from mark recapture are also available. They also show a tendency to underestimate the true population size (Neal et al. 1993; Bartmann et al. 1987). It is expected that the population estimate of salmon entering Paradise River in 1999 of 5,172 may be an overestimate by some 10-15% as mark-recapture techniques tend to overestimate the true population size; although it is still useful.

A number of seals of three species (ranger, grey, and bearded) were observed on a daily basis in Paradise River in 1998 and 1999, in the estuary and as far up as the recapture traps in Folletts Pond which is about 12 km from the estuary. They are undoubtedly feeding on fish resources in the river. The seal populations and their feeding habits should be investigated further.

ACKNOWLEDGEMENTS

The hard work of the staff of Sandwich Bay Watershed Management Authority who set out and hauled the nets used to catch and tag salmon and the support of DFO Fisheries Officers J. Burdett, H. Heard and G. Bird of Fisheries and Oceans Canada are gratefully acknowledged. The advice of C. Lethbridge in planning this project was quintessential to its success.

REFERENCES

Anderson, T. C. and B. P. McDonald. 1978. A portable weir for counting migrating fishes in rivers. Fish. Mar. Serv. Tech. Rep. 733: 13 p.

Anderson, T. C. 1985. The Rivers of Labrador. Can. Spec. Publ. Fish. Aquat. Sci. 81: 389p.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106.

Atkinson, G., G. Sanipass, V. LeBlanc, S. LeBlanc, and N. LeBlanc. 1999. Status of Atlantic salmon (*Salmo salar*) in the Buctouche River in 1998. CSAS Res. Doc. 99/27, 23 p.

Bartmann, R., G. C. White, L. H. Carpenter, and R. A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in Pinyon-Juniper woodland. J. Wildl. Manage. 51(1):41-46.

Chaput, G. J. [Ed.] 1997. Proceedings of a Workshop to review conservation principles for Atlantic salmon in Eastern Canada. CSAS Proceedings Series 97/15, 33 p.

CSAS 1999. Newfoundland & Labrador Atlantic Salmon Stock Status for 1998. DFO Science Stock Status Report D2-01(1999), 19 p.

Elson, P. F. 1957. Using hatchery reared Atlantic salmon to best advantage. Can. Fish. Cult. 21:7-17.

Elson, P. F. 1975. Atlantic salmon rivers, smolt production and optimal spawning: an overview of natural production. Int. Atl. Salmon Found. Spec. Publ. Ser. 6: 96-119.

Gazey, W. J., and M. J. Staley. 1986. Population estimation from mark-recapture experiments using a sequential Bayes algorithm. Ecology 67: 941-951.

Mullins, C. C. and D. Caines 1999. Status of the Atlantic salmon (Salmo salar L.) stock of Humber River, Newfoundland, 1998. DFO Can. Stock Assess. Sec. Res. Doc. 99/100.

Murphy, H. P. 1971. A helicopter reconnaissance survey of Eagle, Paradise and White Bear Rivers, Sandwich Bay, Labrador, August, 1970. Fish. Serv. Res. Dev. Branch Nfld. Reg. Prog. Rep. 83:v + 53 p.

Miyakoshi, Y. and S. Kudo. 1999. Mark-recapture estimation of escapement of Masu salmon (Oncorhynchus masou) with a comparison to a fence count. North American Journal of Fisheries Management 19: 1108-1111.

Neal, A. K., G. C. White, R. B. Gill, D. F. Reed, and J. H. Olterman. 1993. Evaluation of mark-recapture model assumptions for estimating mountain sheep numbers. J. Wildl. Manage. 57(3):436-450.

O'Connell, M. F., J. B. Dempson, and D. G. Reddin. 1997. Inter-annual and inter-river variability in fecundity in Atlantic salmon (Salmo salar L.) in Newfoundland rivers. DFO, CSAS Res. Doc. 97/94, 33 p.

Ottera, H., T. S. Kristiansen, T. Svasand. 1998. Evaluation of anchor tags used in sea-ranching experiments with Atlantic cod (*Gadus morhua* L.). Fisheries Research 35: 237-246.

Petersen, C. G. J. 1896. The yearly immigration of young plaice into the Limfjord from the German Sea, etc. Rep. Dan. Biol. Sta. 6: 1-48.

Pratt, J. D., G. M. Hare, and G. M. Murphy. 1974. Investigations of production and harvest of an Atlantic salmon population, Sand Hill River, Labrador. Fish. Mar. Serv. Res. Dev. Branch Tech. Rep. Ser. No. NEW/T-74-1: iii+ 27p.

Reddin, D. G., P. B. Short, M. F. O'Connell, and A. D. Walsh. 1996. Atlantic salmon stock status for Sand Hill River, Labrador, 1995. DFO, Atlantic Fisheries

Res. Doc. 96/82. 32 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Fig. 1. Location map depicting Labrador, Salmon Fishing Areas (SFAs) with Sandwich Bay and Paradise River.

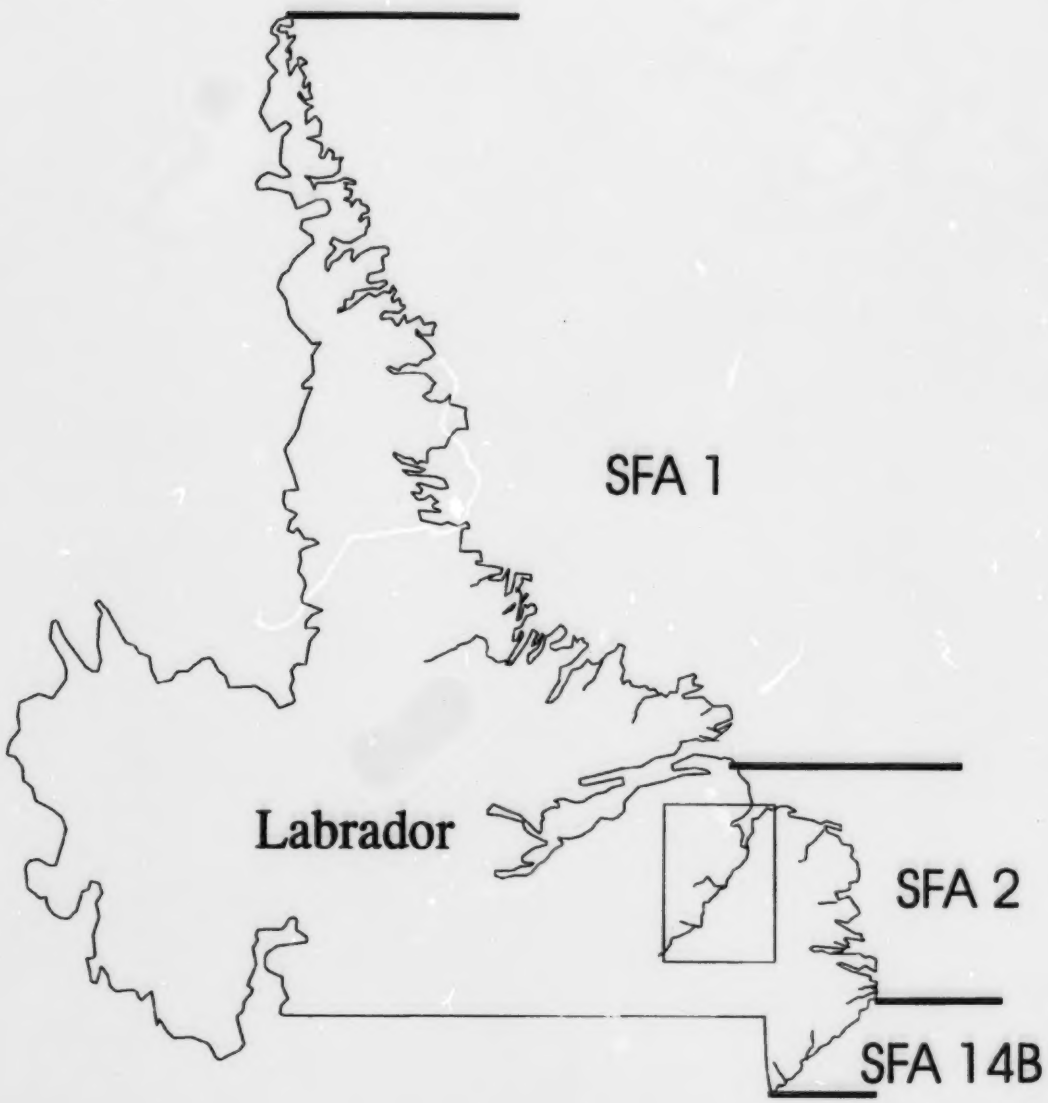


Fig. 2. Paradise River with tributaries and partial obstructions.

Fig. 3 Paradise River Tagging and Recapture Sites

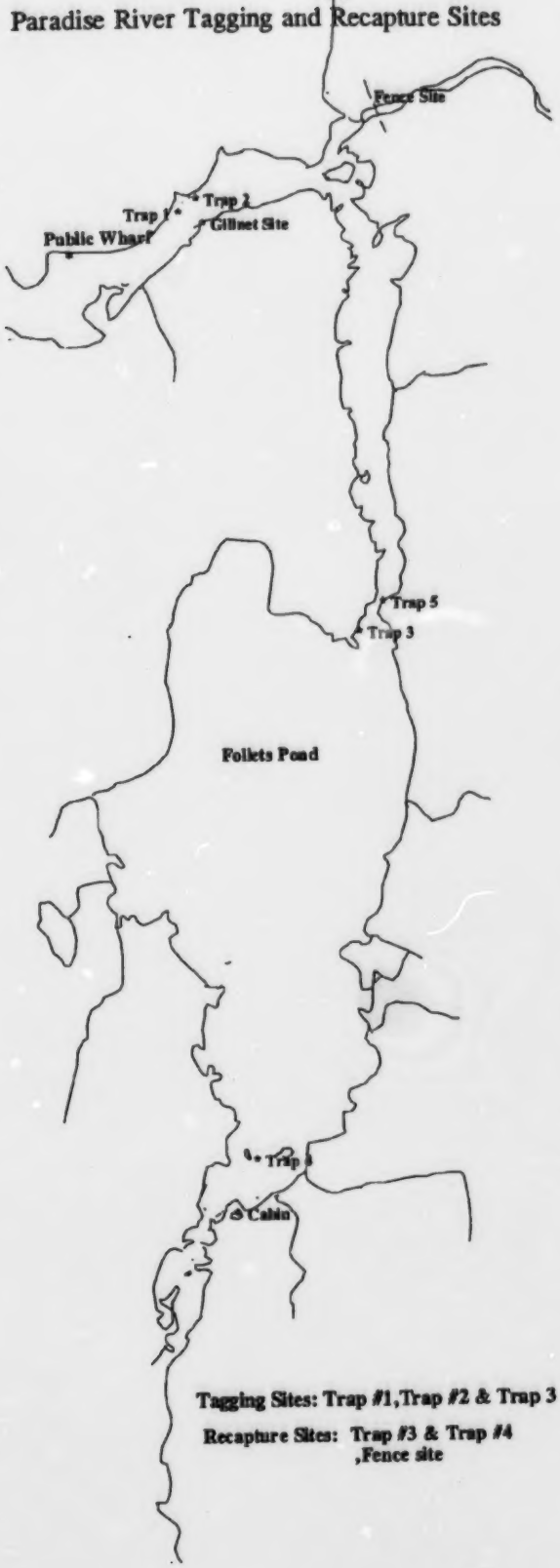


Fig. 4. Small and large salmon counted at Southwest Brook, Paradise River, 1999.

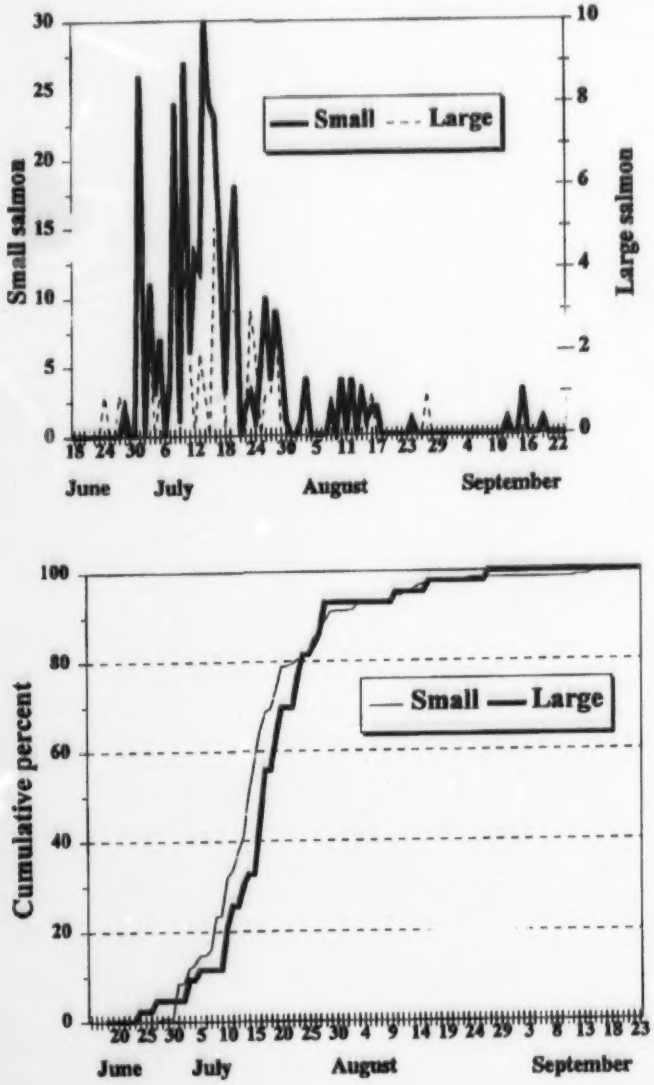
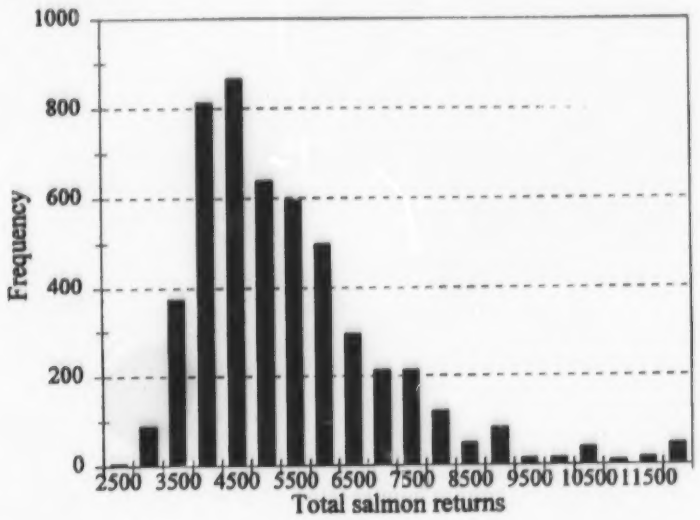


Fig. 5. Frequency distribution of the estimated total returns to Paradise River, 1999 (upper panel) and the corresponding probability distribution (lower panel). Total salmon returns are at the lower end of the range used for each interval.



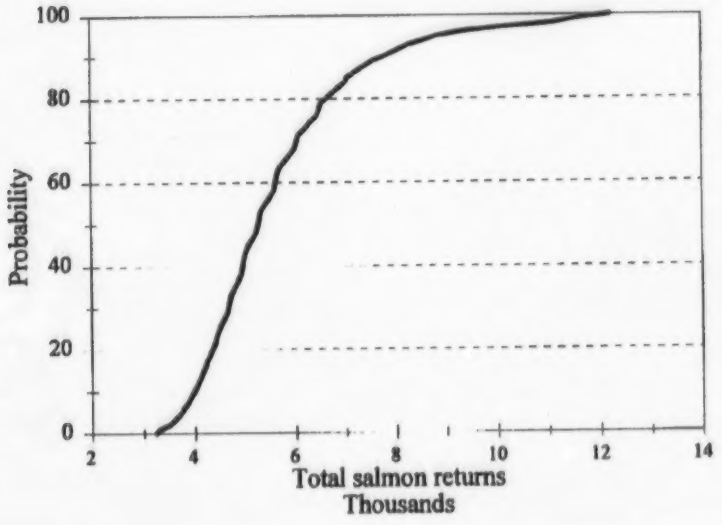


Fig. 8. Water temperatures and levels at Southwest Brook counting fence, Paradise River, 1999. Dashed line is water level and solid lines are minimum and maximum daily water temperatures.

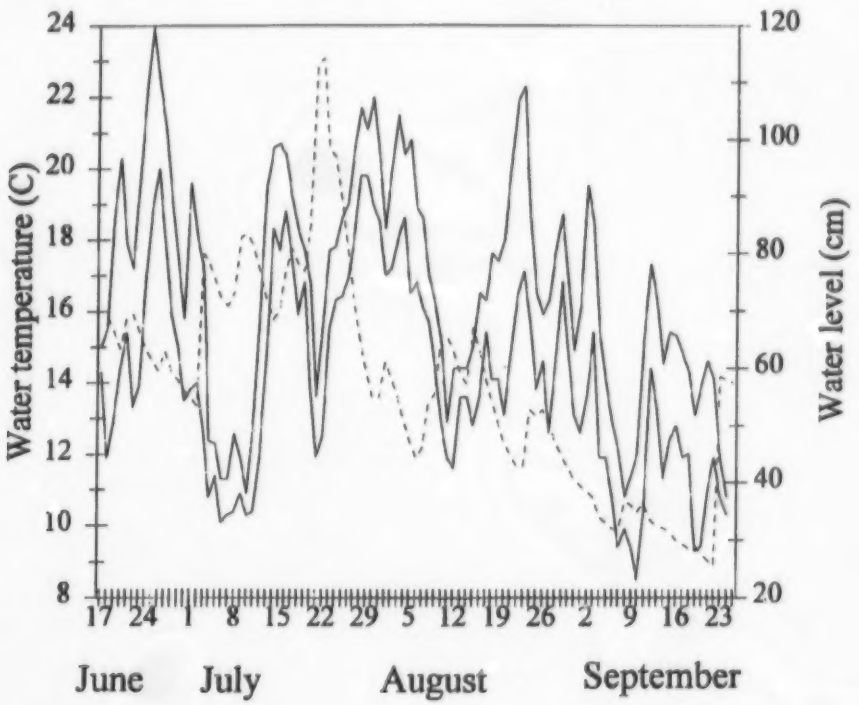


Fig. 7. Frequency distribution of the estimated percent of conservation requirement met at Paradise River, 1999 (upper panel) and the corresponding probability distribution (lower panel). Percent of conservation requirements met are at the low end of the range of each interval.

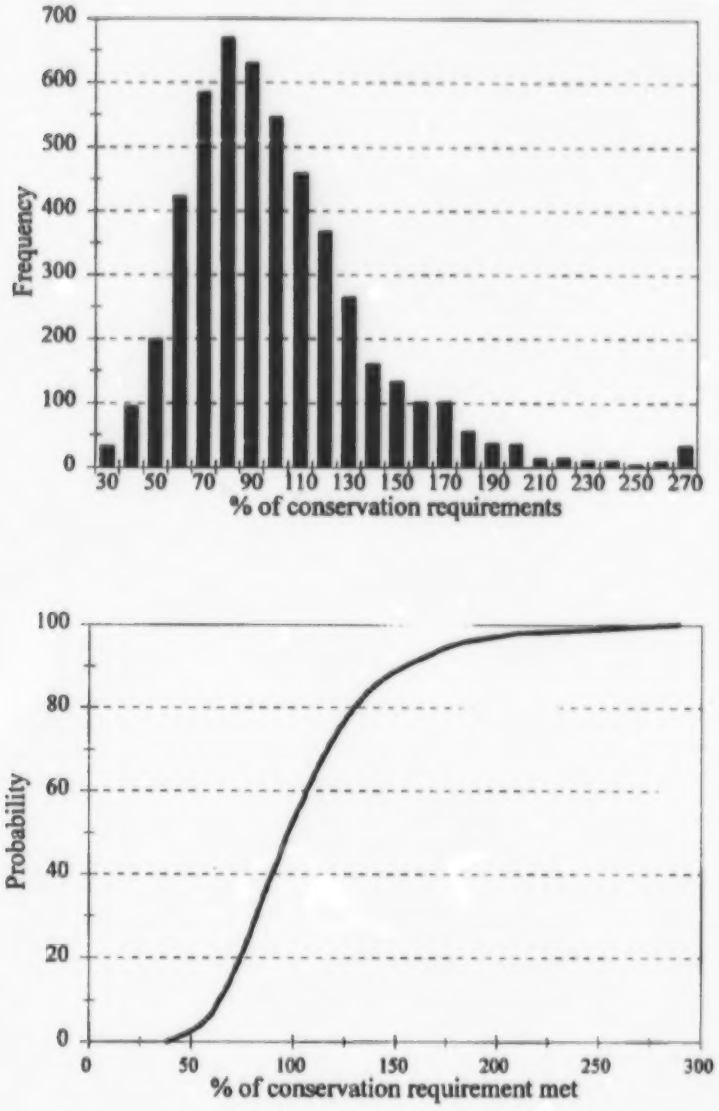
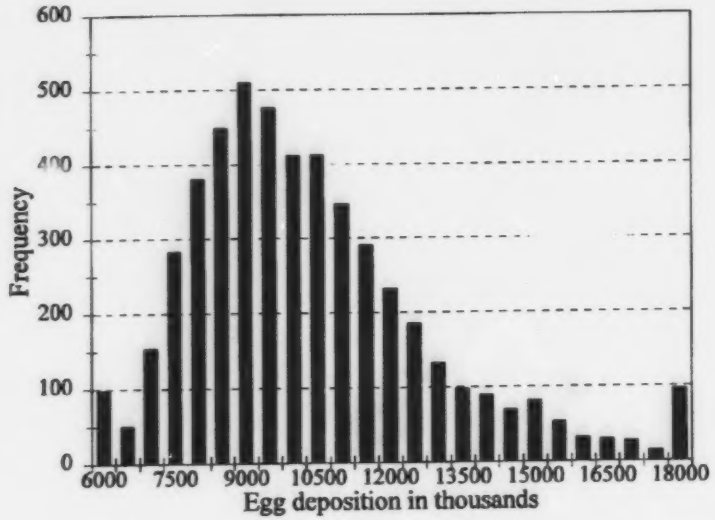


Fig. 6. Frequency distribution of the estimated egg deposition at Paradise River, 1999 (upper panel) and the corresponding probability distribution (lower panel). Egg depositions are at the low point of the range for each interval.



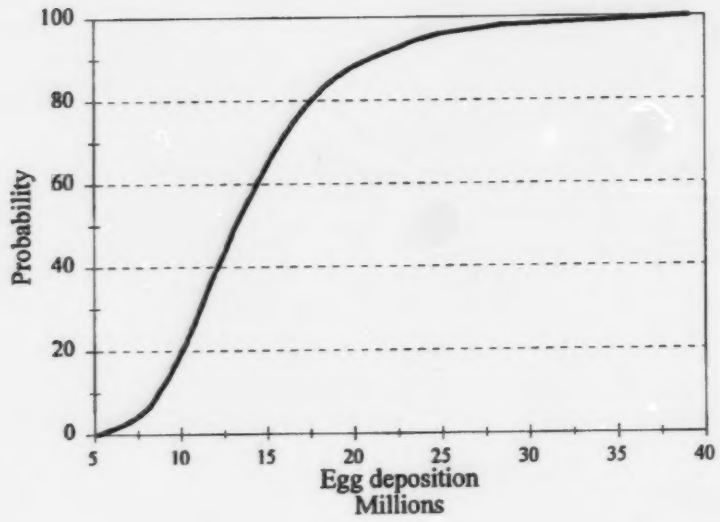


Table 1. Record of fish counts at Southwest Brook counting fence, 1998-99.

Date	1998				1999			
	Small salmon	Large salmon	Trout	Sculpin	Small salmon	Large salmon	Trout	Sculpin
June 18	-	-	-	-				1
June 19	-	-	-	-				15
June 20	-	-	-	-			1	8
June 21	-	-	-	-			3	4
June 22	-	-	-	-				7
June 23	-	-	-	-				9
June 24	-	-	-	-		1	1	11
June 25	-	-	-	-			1	
June 26	-	-	-	-				
June 27	-	-	-	-		1	1	
June 28	-	-	-	-	2			
June 29	-	-	-	-			1	
June 30	-	-	-	-				
July 1	-	-	-	-	26			
July 2	-	-	-	-				
July 3	-	-	-	-	11	2		
July 4	-	-	-	-	3			
July 5	-	-	-	-	7	1		
July 6	-	-	-	-				
July 7	-	-	-	-	4		2	
July 8	-	-	-	-	24		1	
July 9	-	-	-	-	1		1	
July 10	-	-	-	-	27	4		
July 11	-	-	-	-	6	2		
July 12	-	-	-	-	13		1	6
July 13					12	2	2	
July 14	6		1		30	1	1	
July 15					24		1	
July 16	1		3		23	5		
July 17	2		1		14	5		
July 18	1				3		3	
July 19	5				13	3		
July 20	1				18	3		
July 21						0		
July 22			1		2	0		
July 23	3		1		3	3		
July 24	2		2		1	2		
July 25	2		4		5	0	6	
July 26	4		4		10	1		
July 27	1		7	1	4	1	2	
July 28	3		13	1	8	3		
July 29	3		18		6	0	4	
July 30	3		24		1	0		
July 31	5		23			0	0	
Aug 1			8		0	0	5	
Aug 2			7		1	0	23	
Aug 3	2		6		4	0	38	
Aug 4			4				24	
Aug 5			3				5	
Aug 6			6	1			3	
Aug 7	1		10				7	
Aug 8			3		2		8	
Aug 9	9		8				5	
Aug 10	5		7		4	1	10	
Aug 11			1				2	
Aug 12					4		27	
Aug 13							8	
Aug 14			3		3		4	
Aug 15					1		24	
Aug 16					2	1	12	
Aug 17	8	2	7		2			
Aug 18			1				15	
Aug 19							2	
Aug 20				1			13	
Aug 21				1			1	
Aug 22			6				16	
Aug 23			1					
Aug 24				3	1		1	
Aug 25	3		1				1	
Aug 26			1					
Aug 27				2		1	2	
Aug 28			1					
Aug 29							6	
Aug 30								
Aug 31								
Sept 1								
Sept 2			1				1	
Sept 3	1							
Sept 4	1						2	
Sept 5								
Sept 6								
Sept 7		1						
Sept 8								
Sept 9								
Sept 10		-	-	-	-			
Sept 11		-	-	-	-			
Sept 12		-	-	-	-	1		4
Sept 13		-	-	-	-			
Sept 14		-	-	-	-			
Sept 15		-	-	-	-	3		
Sept 16		-	-	-	-			
Sept 17		-	-	-	-			
Sept 18		-	-	-	-			
Sept 19		-	-	-	-	1		
Sept 20		-	-	-	-			
Sept 21		-	-	-	-			1
Sept 22		-	-	-	-			
Sept 23		-	-	-	-			
TOTAL		67	3	187	10	331	43	310	61

Table 2a. Daily counts and totals adjusted for non-operational period of upstream migrating Atlantic salmon at Southwest Brook (Paradise River), Labrador in 1998. Fence in operation from July 13, 1998 to Sept 9, 1998.

DATE	Number of salmon SMALL	LARGE	Cumulative numbers SMALL	LARGE	TOTAL	Cumulative percentages SMALL	LARGE	TOTAL	% large salmon	Trout	Cumulative Number	Percent
18 June	-	-	-	-	0	0.0	0.0	0.0	0	-	-	0.0
19 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
20 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
21 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
22 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
23 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
24 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
25 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
26 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
27 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
28 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
29 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
30 June	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
1 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
2 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
3 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
4 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
5 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
6 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
7 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
8 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
9 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
10 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
11 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
12 July	-	-	0	0	0	0.0	0.0	0.0	0	-	0	0.0
13 July	0	0	0	0	0	0.0	0.0	0.0	0	-	0	0.0
14 July	5	0	5	0	5	7.5	0.0	7.1	0	1	1	0.5
15 July	0	0	5	0	5	7.5	0.0	7.1	0	0	1	0.5
16 July	1	0	6	0	6	9.0	0.0	8.6	0	3	4	2.1
17 July	2	0	8	0	8	11.9	0.0	11.4	0	1	5	2.7
18 July	1	0	9	0	9	13.4	0.0	12.9	0	0	5	2.7
19 July	5	0	14	0	14	20.9	0.0	20.0	0	0	5	2.7
20 July	1	0	15	0	15	22.4	0.0	21.4	0	0	5	2.7
21 July	0	0	15	0	15	22.4	0.0	21.4	0	0	5	2.7
22 July	0	0	15	0	15	22.4	0.0	21.4		1	6	3.2
23 July	3	0	18	0	18	26.9	0.0	25.7	0	1	7	3.7
24 July	2	0	20	0	20	29.9	0.0	28.6	0	2	9	4.8
25 July	2	0	22	0	22	32.8	0.0	31.4	0	4	13	7.0
26 July	4	0	26	0	26	38.8	0.0	37.1	0	4	17	9.1
27 July	1	0	27	0	27	40.3	0.0	38.6	0	7	24	12.8
28 July	3	0	30	0	30	44.8	0.0	42.9	0	13	37	19.8
29 July	3	0	33	0	33	49.3	0.0	47.1	0	18	55	29.4
30 July	3	0	36	0	36	53.7	0.0	51.4	0	24	79	42.2
31 July	5	0	41	0	41	61.2	0.0	58.6	0	23	102	54.5
1 August	0	0	41	0	41	61.2	0.0	58.6	0	8	110	58.8
2 August	0	0	41	0	41	61.2	0.0	58.6		7	117	62.6
3 August	2	0	43	0	43	64.2	0.0	61.4	0	6	123	65.8
4 August	0	0	43	0	43	64.2	0.0	61.4	0	4	127	67.9
5 August	0	0	43	0	43	64.2	0.0	61.4	0	3	130	69.5
6 August	0	0	43	0	43	64.2	0.0	61.4	0	6	136	72.7
7 August	1	0	44	0	44	65.7	0.0	62.9	0	10	146	78.1
8 August	0	0	44	0	44	65.7	0.0	62.9		3	149	79.7
9 August	9	0	53	0	53	79.1	0.0	75.7	0	8	157	84.0
10 August	3	0	56	0	56	83.6	0.0	80.0	0	7	164	87.7
11 August	0	0	56	0	56	83.6	0.0	80.0	0	1	165	88.2
12 August	0	0	56	0	56	83.6	0.0	80.0		0	165	88.2
13 August	0	0	56	0	56	83.6	0.0	80.0	0	0	165	88.2
14 August	0	0	56	0	56	83.6	0.0	80.0		3	168	89.8
15 August	0	0	56	0	56	83.6	0.0	80.0		0	168	89.8
16 August	0	0	56	0	56	83.6	0.0	80.0		0	168	89.8
17 August	6	2	62	2	64	92.5	66.7	91.4	25	7	175	93.6
18 August	0	0	62	2	64	92.5	66.7	91.4	0	1	176	94.1
19 August	0	0	62	2	64	92.5	66.7	91.4	0	0	176	94.1
20 August	0	0	62	2	64	92.5	66.7	91.4	0	0	176	94.1
21 August	0	0	62	2	64	92.5	66.7	91.4	0	0	176	94.1
22 August	0	0	62	2	64	92.5	66.7	91.4	0	6	182	97.3
23 August	0	0	62	2	64	92.5	66.7	91.4	0	1	183	97.9
24 August	0	0	62	2	64	92.5	66.7	91.4		0	183	97.9
25 August	3	0	65	2	67	97.0	66.7	95.7	0	1	184	98.4
26 August	0	0	65	2	67	97.0	66.7	95.7	0	1	185	98.9
27 August	0	0	65	2	67	97.0	66.7	95.7		0	185	98.9
28 August	0	0	65	2	67	97.0	66.7	95.7	0	1	186	99.5
29 August	0	0	65	2	67	97.0	66.7	95.7	0	0	186	99.5
30 August	0	0	65	2	67	97.0	66.7	95.7	0	0	186	99.5
31 August	0	0	65	2	67	97.0	66.7	95.7	0	0	186	99.5
1 Sept	0	0	65	2	67	97.0	66.7	95.7	0	1	187	100.0
2 Sept	0	0	65	2	67	97.0	66.7	95.7	0	0	187	100.0
3 Sept	1	0	66	2	68	98.5	66.7	97.1	0	0	187	100.0
4 Sept	1	0	67	2	69	100.0	66.7	98.6	0	0	187	100.0
5 Sept	0	0	67	2	69	100.0	66.7	98.6	0	0	187	100.0
6 Sept	0	0	67	2	69	100.0	66.7	98.6	0	0	187	100.0
7 Sept	0	1	67	3	70	100.0	100.0	100.0	0	0	187	100.0
8 Sept	0	0	67	3	70	100.0	100.0	100.0	0	0	187	100.0
9 Sept	0	0	67	3	70	100.0	100.0	100.0	0	0	187	100.0
10 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
11 Sept	-	-	67	3	70	100.0	100.0	100.0		-	187	100.0
12 Sept	-	-	67	3	70	100.0	100.0	100.0		-	187	100.0
13 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
14 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
15 Sept	-	-	67	3	70	100.0	100.0	100.0		-	187	100.0
16 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
17 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
18 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
19 Sept	-	-	67	3	70	100.0	100.0	100.0		-	187	100.0
20 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
21 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
22 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
23 Sept	-	-	67	3	70	100.0	100.0	100.0	0	-	187	100.0
Total	67	3							4	187		
Total corrected	110	4								199		

Table 2b. Daily counts of upstream migrating Atlantic salmon at Southwest Brook (Trepassey River), Labrador in 1999. Fence in operation from June 18, 1999 to Sept 23, 1999.

DATE	Number of fish		Cumulative numbers			Cumulative percentages			% large salmon	Trout	Cumulative	
	SMALL	LARGE	SMALL	LARGE	TOTAL	SMALL	LARGE	TOTAL			Number	Percent
18 June	0	0	0	0	0	0.0	0.0	0.0		0	0	0.0
19 June	0	0	0	0	0	0.0	0.0	0.0		0	0	0.0
20 June	0	0	0	0	0	0.0	0.0	0.0		1	1	0.3
21 June	0	0	0	0	0	0.0	0.0	0.0		3	4	1.3
22 June	0	0	0	0	0	0.0	0.0	0.0		0	4	1.3
23 June	0	0	0	0	0	0.0	0.0	0.0		0	4	1.3
24 June	0	1	0	1	1	0.0	2.3	0.3	100	1	5	1.6
25 June	0	0	0	1	1	0.0	2.3	0.3		1	6	1.9
26 June	0	0	0	1	1	0.0	2.3	0.3		0	6	1.9
27 June	0	1	0	2	2	0.0	4.7	0.5	100	1	7	2.3
28 June	2	0	2	2	4	0.6	4.7	1.1	0	0	7	2.3
29 June	0	0	2	2	4	0.6	4.7	1.1		1	8	2.6
30 June	0	0	2	2	4	0.6	4.7	1.1		0	8	2.6
1 July	26	0	28	2	30	8.3	4.7	8.0	0	0	8	2.6
2 July	0	0	28	2	30	8.3	4.7	8.0		0	8	2.6
3 July	11	2	39	4	43	11.8	9.3	11.5	15	0	8	2.6
4 July	3	0	42	4	46	12.7	9.3	12.3	0	0	8	2.6
5 July	7	1	49	5	54	14.8	11.6	14.4	13	0	8	2.6
6 July	0	0	49	5	54	14.8	11.6	14.4		0	8	2.6
7 July	4	0	53	5	58	16.0	11.6	15.5	0	2	10	3.2
8 July	24	0	77	5	82	23.3	11.6	21.9	0	1	11	3.5
9 July	1	0	78	5	83	23.6	11.6	22.2	0	1	12	3.9
10 July	27	4	105	9	114	31.7	20.9	30.5	13	0	12	3.9
11 July	6	2	111	11	122	33.5	25.6	32.6	25	0	12	3.9
12 July	13	0	124	11	135	37.5	25.6	36.1	0	1	13	4.2
13 July	12	2	136	13	149	41.1	30.2	39.8	14	2	15	4.8
14 July	30	1	166	14	180	50.2	32.6	48.1	3	1	16	5.2
15 July	24	0	190	14	204	57.4	32.6	54.5	0	1	17	5.5
16 July	23	5	213	19	232	64.4	44.2	62.0	18	0	17	5.5
17 July	14	5	227	24	251	68.6	55.8	67.1	26	0	20	6.5
18 July	3	0	230	24	254	69.5	55.8	67.9	0	2	20	6.5
19 July	13	3	243	27	270	72.4	62.8	72.2	19	0	20	6.5
20 July	18	3	261	30	291	78.9	69.8	77.8	14	0	20	6.5
21 July	0	0	261	30	291	78.9	69.8	77.8		0	20	6.5
22 July	2	0	263	30	293	79.5	69.8	78.3	0	0	20	6.5
23 July	3	3	266	33	299	80.4	76.7	79.9	50	0	20	6.5
24 July	1	2	267	35	302	80.7	81.4	80.7	67	0	20	6.5
25 July	5	0	272	35	307	82.2	81.4	82.1	0	4	24	7.8
26 July	10	1	282	36	318	85.2	83.7	85.0	9	0	24	7.8
27 July	4	1	286	37	323	86.4	86.0	86.4	20	2	26	8.4
28 July	9	3	295	40	335	89.1	93.0	89.6	25	0	26	8.4
29 July	6	0	301	40	341	90.9	93.0	91.2	0	4	30	9.8
30 July	1	0	302	40	342	91.2	93.0	91.4	0	0	30	9.8
31 July	0	0	302	40	342	91.2	93.0	91.4		0	30	9.8
1 August	0	0	302	40	342	91.2	93.0	91.4		5	35	11.4
2 August	1	0	303	40	343	91.5	93.0	91.7	0	23	58	19.0
3 August	4	0	307	40	347	92.7	93.0	92.8		36	94	30.8
4 August	0	0	307	40	347	92.7	93.0	92.8		24	118	38.7
5 August	0	0	307	40	347	92.7	93.0	92.8		5	123	40.3
6 August	0	0	307	40	347	92.7	93.0	92.8		3	126	41.3
7 August	0	0	307	40	347	92.7	93.0	92.8		7	133	43.5
8 August	2	0	309	40	349	93.4	93.0	93.3	0	9	142	46.5
9 August	0	0	309	40	349	93.4	93.0	93.3		5	147	48.1
10 August	4	1	313	41	354	94.6	95.3	94.7	20	19	166	54.2
11 August	0	0	313	41	354	94.6	95.3	94.7		2	168	54.8
12 August	4	0	317	41	358	95.8	95.3	95.7	0	27	195	63.5
13 August	0	0	317	41	358	95.8	95.3	95.7		8	203	66.1
14 August	3	0	320	41	361	96.7	95.3	96.5	0	4	207	67.4
15 August	1	0	321	41	362	97.0	95.3	96.8	0	26	233	75.2
16 August	2	1	323	42	365	97.6	97.7	97.6	33	12	245	79.0
17 August	2	0	325	42	367	98.2	97.7	98.1	0	0	245	79.0
18 August	0	0	325	42	367	98.2	97.7	98.1		15	260	83.9
19 August	0	0	325	42	367	98.2	97.7	98.1		2	262	84.5
20 August	0	0	325	42	367	98.2	97.7	98.1		13	275	88.7
21 August	0	0	325	42	367	98.2	97.7	98.1		1	276	89.0
22 August	0	0	325	42	367	98.2	97.7	98.1		16	292	94.2
23 August	0	0	325	42	367	98.2	97.7	98.1		0	292	94.2
24 August	1	0	326	42	368	98.5	97.7	98.4	0	1	293	94.5
25 August	0	0	326	42	368	98.5	97.7	98.4		1	294	94.8
26 August	0	0	326	42	368	98.5	97.7	98.4		0	294	94.8
27 August	0	1	326	43	369	98.5	100.0	98.7	100	2	296	95.5
28 August	0	0	326	43	369	98.5	100.0	98.7		0	296	95.5
29 August	0	0	326	43	369	98.5	100.0	98.7		6	302	97.4
30 August	0	0	326	43	369	98.5	100.0	98.7		0	302	97.4
31 August	0	0	326	43	369	98.5	100.0	98.7		0	302	97.4
1 Sept	0	0	326	43	369	98.5	100.0	98.7		1	303	97.7
2 Sept	0	0	326	43	369	98.5	100.0	98.7		0	303	97.7
3 Sept	0	0	326	43	369	98.5	100.0	98.7		2	305	98.4
4 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
5 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
6 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
7 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
8 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
9 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
10 Sept	0	0	326	43	369	98.5	100.0	98.7		0	305	98.4
11 Sept	0	0	326	43	369	98.5	100.0	98.7	0	4	309	99.7
12 Sept	1	0	327	43	370	98.8	100.0	98.9		0	309	99.7
13 Sept	0	0	327	43	370	98.8	100.0	98.9		0	309	99.7
14 Sept	0	0	327	43	370	98.8	100.0	98.9		0	309	99.7
15 Sept	3	0	330	43	373	99.7	100.0	99.7	0	0	309	99.7
16 Sept	0	0	330	43	373	99.7	100.0	99.7		0	309	99.7
17 Sept	0	0	330	43	373	99.7	100.0	99.7		0	309	99.7
18 Sept	0	0	330	43	373	99.7	100.0	99.7		0	309	99.7
19 Sept	1	0	331	43	374	100.0	100.0	100.0	0	0	309	99.7
20 Sept	0	0	331	43	374	100.0	100.0	100.0		0	309	99.7
21 Sept	0	0	331	43	374	100.0	100.0	100.0		1	310	100.0
22 Sept	0	0	331	43	374	100.0	100.0	100.0		0	310	100.0
23 Sept	0	0	331	43	374	100.0	100.0	100.0		0	310	100.0
Total	331	43							11	310		
Total for Jul 13-Sep 9	280	33								291		

Table 3. Summary of tag release and recapture dates from counting fence on Southwest Brook and recapture traps in Follets Pond, Paradise River, 1999.

Release date	Recapture date	Days free	Location	Lifestage
June 24	July 4	10	SW	S
June 24	July 4	10	Trap 3	S
June 24	July 28	34	SW	S
June 24	July 5	11	Trap 3	L
June 24	July 13	19	SW	S
June 25	July 1	6	SW	S
June 25	July 9	14	SW	S
June 25	July 15	20	SW	S
June 27	July 3	6	SW	S
June 28	July 18	20	SW	S
June 28	July 19	21	SW	S
June 29	July 20	21	SW	S
July 1	July 8	7	SW	S
July 8	August 12	35	SW	S
July 16	July 18	2	Trap 3	S
July 19	July 29	10	SW	S
July 19	August 14	26	SW	L
July 28	August 4	7	Trap 4	L
July 28	September 15	49	SW	S

Table 4a. Summary of tags applied, tag recaptures, and non-marked small salmon caught for Paradise River mark-recapture study, 1999.

Location	Catch	Recaptures	Marked (available)
Estuary (traps & gillnets)	145	-	143
Southwest Brook fence	331	14	-
Folletts Pond			
Trap #3	159	2	-
Trap #4	45	0	-
Total	204	2	-
Total	535	16	143

Table 4b. Summary of tags applied, tag recaptures, and non-marked large salmon caught for Paradise River mark-recapture study, 1999.

Location	Catch	Recaptures	Marked (available)
Estuary (traps & gillnets)	11	- -	11
Southwest Brook fence	43	1	-
Folletts Pond			
Trap #3	12	1	-
Trap #4	5	0	-
Total	17	1	-
Total	60	2	11

Table 7. Parameters, values, and distributions used in assessment of risk. Output generated from 5,000 realizations.

Variable name	Symbol	Unit	Estimator	Parameter value	Distribution	Source
Small salmon	Sm	number	C*R/M[1]	3500-7650	Binomial	Paradise River mark recapture
Large salmon	Lg	number	$Sm*P_l$	335-850	Binomial	Samples from Paradise River
Total salmon	T	number	Sm + Lg	Output	Generated	
Proportion large	P_l	proportion	Lg/Sm	0.059-0.14	Binomial	Samples from Paradise River
Fork length		cm	Mean		Uniform	Samples from Paradise River
Small	FL_s			50-62		
Large	FL_l			56-83		
Proportion female		proportion	Females/(Females+Males		Binomial	Samples from Paradise River
Small	PF_s			0.21-1		
Large	PF_l			0.21-1		
Relative fecundity		eggs per cm			Uniform	Sand Hill River, 1994-95
Small	RF_s			54-82		
Large	RF_l			54-82		
Eggs deposited		number		Output	Generated	
Small	ED_s					
Large	ED_l					
Conservation requirements	CR	number		Single no.	Generated	From 240 eggs per unit (Chaput 1997)
% CR met	% met	%		Output	Generated	

[1] Petersen formula to estimate population size

Table 6. Adult salmon returns, spawning escapment and egg depositions for Paradise River, Labrador in 1999.

SPAWNING ESCAPEMENT $SE = TRR - (AC) - (HRM), HRM = (HRC * 0.1)$

SE= Spawning escapment
TRR= Total returns to river ($FC + AC_b + HRM_b$)
FC= Fence count
AC= Angling catch (retained)
HRC= Hook & release catch
HRM= Hook & release mortalities evaluated as 10% of HRC (HRC * 0.10)
a & b= subscripts denoting above and below the counting fence

		1999	Average
TRR	Small	4681	4681
	Large	491	491
AC_a	Small	0	0
	Large	0	0
HRC_a	Small	0	0
	Large	0	0
AC_b	Small	0	0
	Large	0	0
HRC_b	Small	0	0
	Large	0	0
SE	Small	4681	4681
	Large	491	491

EGG DEPOSITION $ED = SE * PF * RF * FL$

ED= Egg deposition
SE= Spawning escapment
PF= Proportion females
RF= Relative fecundity (eggs/cm)
FL= Mean fork length of female salmon

	Year	1999	AVERAGE
SE	Small	4681	4681
	Large	491	491
PF	Small	0.643	0.643
	Large	0.643	0.643
RF[1]	Small	68.2	68.2
	Large	67.5	67.5
FL	Small	56.3	56.3
	Large	69.5	69.5
ED	Small	11556927	11556927
	Large	1481089	1481089
Total		13038016	13038016
Conservation require		13543000	5294160
% requirements met		96	246

[1] in the absence of fecundity values for Paradise River, Sand Hill River values were used

Table 5. Biological characteristic data for tagged salmon and mortalities from Paradise River, Labrador, 1999. NA - not available.

Class	Type	Fork length (cm)	Whole weight	Percent of Group	Percent female		River age distribution 1	2	3	4	5	6	7	Total
Small salmon	Mean	56.3	2.29	91.8	64.3	Number	0	1	23	80	52	10	3	169
	SD	2.92	0.451	-	-	Percent	0	1	14	47	31	6	2	100
	N	190	10	190	14									
Large salmon	Mean	69.5	5.6	8.2	NA	Number	0	0	3	10	2	0	0	15
	SD	6.75	-	-		Percent	0	0	20	67	13	0	0	100
	N	17	1	17										
Grilse	Mean	58.6	2.29	95.1	NA	Number	0	1	25	84	54	10	3	177
	SD	3.304	0.451	-		Percent	0	1	14	47	31	6	2	100
	N	190	10	193										
2SW	Mean	75.3	5.6	3.4	NA	Number	0	0	0	6	1	0	0	7
	SD	3.73	-	-		Percent	0	0	0	86	14	0	0	100
	N	7	1	7										
Repeat spawners	Mean	64.7	-	1.5	NA	Number	0	0	1	1	1	0	0	3
	SD	13.4	-	-		Percent	0	0	33	33	33	0	0	100
	N	3	-	3										
All salmon	Mean	57.4	2.59	NA	64.3	Number	0	1	26	91	56	10	3	187
	SD	4.95	1.09		-	Percent	0	1	14	49	30	5	2	100
	N	207	11		14									